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Approaches to Valuation in LCA Impact Assessment

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Abstract

One of the major problems with the future development of lifecycle assessment is the difficulty in converting lifecycle inventory results into environmental impacts, owing to problems associated with the interpretation and weighting of the data. The four main valuation approaches: distance-to-target, environmental control costs, environmental damage costs and scoring approaches are assessed and the individual methodologies evaluated. In conclusion it is considered that in a country which has clear, up-to-date, politically acceptable emission standards, a distance-to-target valuation system maybe acceptable. However, these circumstances are likely to be rare, and the choice of standards arbitrary and not scientifically based. Therefore a better choice is probably environmental damage costs, provided suitable economic damage figures are available.

Keywords: Lifecycle assessment; impact assessment; valuation; environmental damage costs

1 Introduction

Lifecycle assessment (LCA) has considerable potential for the assessment of alternative environmental options, particularly in non-product areas, for example consumer services such as waste management. A major barrier, however, is the difficulty in converting lifecycle inventory results into environmental impacts, owing to problems associated with the interpretation and weighting of the data. In any decision making process, unless the outcome is obvious, weights need to be attributed to the impacts according to their relative importance. This is a highly subjective and controversial process.

Due to the difficulty of weighting the data relatively few LCAs include a valuation of the inventory results. LCA practitioners such as VIRTANEN & NILSSON (1993) generally confine the LCAs to the inventory stage. JOHNSON (1993) has taken her analyses one stage further and has classified the inventory data into environmental impacts such as global warming and acidification, but no weighting of these impacts was attempted. Of the few non-product studies to include a valuation stage are CRAIGHILL & POWELL (1996), and POWELL et al. (1996) who apply economic valuation to environmental externalities arising from recycling schemes.

In an attempt to overcome the difficulties in applying valuation techniques this paper evaluates the different approaches to LCA valuation, and assesses the main methodologies. There are four main approaches to valuation methodologies: distance-to-target techniques, environmental control costs, economic damage approaches, and scoring techniques. The first three methods may be regarded as instances of **implied social weighting:** that is weights are 'revealed' via the political process of setting environmental standards or via explicit or implicit market valuations. Scoring approaches, however, differ from the first three in that the **constituency of the valuer** is changed to that of some group generally smaller in size than 'society'.

2 Distance-to-Target Techniques

In the distance-to-target approach weights are derived from the extent to which actual environmental performance deviates from some goal or standard. For example, if the ambient concentration of a pollutant is 1.1 mg/m^3 and the goal or standard is 1 mg/m^3, then the weight to be attached to this impact is 10 % since the ambient concentration is 10 % away from the goal. Effectively, the method ranks impacts as being more important the further away society is from achieving the desired standard for that pollutant. Put another way, it focuses on the extent to which society has (so far) failed to achieve environmental standards.

A disadvantage of the distance-to-target approach is that the emission standards may be based on what is politically achievable rather than what is scientifically desirable. Standards are unlikely to be solely scientifically based as they are also governed by technical limitations, the feasibility of supervision and control, and other political factors. Research (HIRD, 1994) has shown that politically determined targets are often agreed upon in an arbitrary fashion. The arguments for setting targets are seldom transparent (LINDEIJER, 1996). Further problems are that targets may relate to different time frames (FINNVEDEN, 1996), and can vary

between countries or be under revision or out of date. Also only emissions that have regulatory standards can be included in the valuation, although equally, it could be argued that those without standards are not of environmental significance. There is also the problem that below the target level effects are assumed to be absent. Finally, there is the issue raised by LINDFORS et al. (1995) that distance-to-target methods are based on the unjustifiable assumption that all targets are equally important. Based on this, FINNVEDEN (1996) questions whether distance-to-target methods are weighting methods at all, but can rather be seen as extended normalisation methods. Many valuation methodologies are based on the distance-to-target approach, for example Swiss ecopoints and the Dutch Environmental Performance Indicators (EPIs).

3 Environmental Control Costs

The weights on this approach are derived from the expenditure necessary to control environmental damage, that is control costs. If it costs £2 to control one unit of pollutant A and £1 to control pollutant B, then A has a weight of twice that of B. The level of control is usually taken to be that required to achieve some environmental standard. There is therefore a generic link with the distance-to-target weighting approach. The underlying rationale here is that society has expressed its 'willingness to pay' for achieving the standard by implicitly voting the expenditure required to achieve the standard.

The main methodology using the control cost approach was developed at the Tellus Institute (1992). Their approach rests on the idea that control costs are approximations of damage costs as revealed through the standard setting procedure. However, damage costs are conceptually different to control costs: the former are a measure of society's loss of well-being; the latter are what it costs society to achieve a given standard. Even if the standard in question reflects what society wants, there are difficulties in equating damage with control costs. If control costs exceeded damage costs, then, rationally, society would not have voted for the standards. The standard only emerges because damage costs are perceived as being greater than control costs. In this idealised context it could be argued that control costs are minimum estimates of damage costs. Nevertheless two minimum estimates based on control costs could be the same but the 'true' damage costs could be vastly different.

4 Environmental Damage Costs

The weights in this approach come from explicit or implicit measures of willingness to pay (WTP) to avoid the impacts identified in the LCA. They differ from the control cost approach because they are derived from WTP to avoid damage, rather than the WTP as 'revealed' in the costs of controlling damage. Damages may be higher or lower than the costs of control and this approach does not therefore confer any special status on the standards that may be set by central or local authorities.

Economic values are available for a number of impacts including air pollution, casualties from road traffic accidents and road congestion. Hence, the use of monetary values allows the inclusion of a number of social as well as environmental impacts. A clear advantage of this methodology is that although the economist's task of estimating the damage costs is time consuming, the use of these data by the LCA practitioner is relatively simple. In particular, the stages of characterisation or normalisation are not required. For example, it is not necessary to aggregate greenhouse gas emissions into carbon dioxide equivalents. Indeed it is disadvantageous to do so because the relative damage contribution of a greenhouse gas will vary over time and in general be different from its relative forcing capacity (FANKHAUSER, 1994). Another advantage is that in a decision making situation where the financial cost is very important, damage costs can be added to financial costs. However this methodology is still an evolving technique and so at present this approach is limited by the economic damage estimates available. Another potential problem is the acceptability of the use of individual preferences as a policy guide; individuals may not be informed, for example. These issues are discussed in PEARCE (1994).

The combination of LCA and economic valuation is relatively new. So it is useful to look at the methods economists use to estimate the value that individuals place on non-market goods and services. There are two broad approaches; direct methods which are derived from individuals stated 'willingness to pay' (stated preferences) usually by the use of questionnaire surveys; and indirect methods which are based on a consumer's actual, observed, behaviour (revealed preferences) (PEARCE et al, 1989). The main direct method is contingent valuation, while indirect methods include travel costs, hedonic pricing, replacement costs and dose-response techniques.

4.1. Contingent valuation: The general public are asked directly what they are willing to pay to gain or avoid some change in provision of a good or service. e.g. what they would be willing to pay to have a kerbside recycling scheme instead of a 'bring' scheme as a measure of social implications of the two types of schemes.

4.2 Travel cost: Many natural resources, such as lakes and forests are used extensively for recreation, but it is often difficult to value these resources because no prices generally exist for them. Travel costs use the costs of travelling to the site both in terms of time and money to derive economic valuations.

4.3 Hedonic pricing is based on changes in the price of associated goods that do have markets. For example if two identical properties differ only in the local air quality, then the difference in their value can be viewed as the implicitly price of the difference in air quality. Of course properties generally differ in many ways but the implicit prices may be uncovered if the data and statistical prices are good enough.

4.4. Replacement cost is based on the cost of replacing or restoring a damaged asset to its original state, and uses this cost as a measure of the benefit of restoration. This method is widely used because it is relatively easy to find estimates of such costs, but is not actually a proper measure of damage.

4.5. Dose-response: This technique uses market prices to value some environmental impact. When the impact shows up in changes in the quantity or price of marketed inputs or outputs the value of the change can be measured. This technique is used extensively where dose-response relationships between some cause of damage such as pollution and output/impact is known.

5 Scoring Approaches

An alternative approach to valuation is to obtain weightings from a group of experts, or as the allocation of weights is nearly always controversial, a cross section of interested parties, possibly with differing viewpoints. These can include environmental, consumer, and business groups, who reflect the relevant scientific and social opinions. The opinion of the general public can also be sought. In all cases numerical weights are applied to each impact and the weighted impacts are then added. Two forms of scoring are required. Firstly to rank the extent to which more or less of a pollutant is important, (i.e. linear relationship or thresholds), and secondly to rank emissions relative to other pollutants and impacts. For example, it requires that NO_x be weighted relative to CO_2 or particulate matter.

Decision theory techniques, such as the Delphi technique, can be used to make the value judgements more explicit, but most experiments have shown that the results are non-repeatable (ENDS report 231, 1994) due to individuals' perceptions of uncertainties and risk (LINDEIJER, 1996). Another disadvantage is that the use of an expert panel is not a practical option for daily applications such as product improvement (GUINÉE, 1993). The practicability of this technique varies inversely with completeness: the more that is covered in the study, the more difficult it becomes to conduct. Completeness is dependent on the number of individuals on the panel and the number of environmental stressors.

The degree of transparency of this methodology depends on which panel technique is used. Some of the techniques combine classification, characterisation and valuation thus reducing the transparency considerably. In the Delphi method transparency is increased by reporting a statistical summary with standard deviations, etc., and the comments of individuals. To improve the reproducibility of the panel method an agreed methodology and set of standard criteria needs to be determined and used. The potential comprehensiveness of the panel method is high because the number of different categories are unlimited. Qualitative criteria can be included in order to allow for knowledge gaps and perceptions of risk (LINDEIJER, 1996), and to reflect political or societal values represented by the panel (BRAUNSCHWEIG et al., 1994). However there is a problem in that the use of experts in the panel results in a high level of knowledge, but they may not represent societal interests, whilst a panel consisting of a more socially representative group may lack the required level of knowledge of the problem under debate.

6 Discussion

From the above it can be seen that weights are either determined by 'experts' or by 'society' (→ *Fig. 1*). 'Social' weights can in turn be categorised as those determined by:

1. representative interest groups;
2. environmental standards and goals as social consensus (including control costs as surrogates for standards);
3. individual preferences via opinion polls or willingness to pay.

While several of the methods combine features of this categorisation, it helps to provide guidance on selecting a weighting procedure. First, much depends on the role that individual preferences should play in determining outcomes. This is a contentious area of environmental policy generally (SAGOFF, 1988; PEARCE, 1994). Competing arguments include: the democratic justification for using individual preferences versus the view that individuals are poorly informed about environmental consequences of policies and actions, and the potential volatility of public opinion over time versus what may be a time-consistent set of expert judgements.

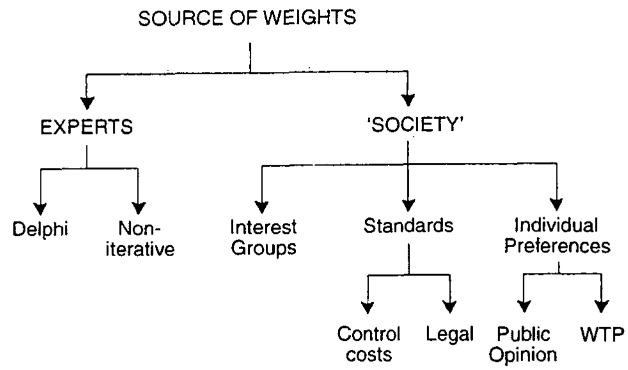

Fig. 1: The determination of weights for LCA valuation

Second, there is an issue of the consistency of the approaches adopted with their own stated aims (assuming those aims are indicated which is not always the case). As an example, it is unclear if control costs are related to social consensus about environmental standards, in the manner implied by the control cost approach. Third, there is the issue of arbitrariness in the selection of the reference group for carrying out the weighting. Experts may be self-appointed or they may reflect some attempt at wider participation in the weighting process (as with the interest group approach). Fourth, the inventory of issues to which weights are applied (a matter only touched on here) must itself have a justification in some reasonably rigorous model of what constitutes 'ecological scarcity'. As we have noted, this rationale is not always present in the approaches adopted.

7 Evaluation of LCA Weighting Schemes

Various criteria can be used to determine the relative desirability of weighting schemes. BRAUNSCHWEIG *et al.* (1994) selected completeness, transparency, content and practicality; while the Society for the Promotion of LCA Development (SPOLD) (GRISEL *et al.*, 1994) selected: objectivity, feasibility, transparency and repeatability. In this paper we suggest the following criteria: transparency, practicality, comprehensiveness, goal consistency and goal acceptability. **Transparency** refers to the extent to which a method is easy to understand and reproduce. **Practicality** includes the

level of simplicity and cost of applying the technique. **Comprehensiveness** indicates that the approach must be capable of deriving weights for at least the most important impacts. **Goal consistency** entails that the goal must be clear and that weights must be consistent with the goal. For **goal acceptability** the goal should be rooted in some form of social acceptability, that is the goal should not reflect unrepresentative interests. Goals should not be arbitrary, nor should they reflect 'false concerns'. Clearly, goal acceptability is tendentious and any evaluation must describe the alternative possibilities.

An evaluation of the various weighting schemes using the criteria set out above is summarised in **Table 1**. Further details of all the schemes can be found in POWELL *et al.* (1995).

8 Conclusion

The selection of a valuation methodology will depend on the user group's objective. A corporation's objective might be one of minimising environmental impact whilst taking into consideration the cost of control. Government may wish to maximise some broad measure of economic well-being, while local government may wish to set a goal related to environmental impact and consistency with planning guidelines. At present, most LCAs are product based and are usually undertaken by companies, but the introduction of LCAs of consumer services such as waste management is likely to introduce a greater range of user groups.

In our evaluation most of the valuation methodologies are moderately transparent, but often involve complex calculations that may be difficult for a non-expert to follow. This is almost inevitable in a complex subject area and should not necessarily penalise the methodology. Practicality in the use of the methodology is, however, essential. Most of the methodologies are easy to use, although several (e.g. Swiss ecopoints) are at present only available for the country of origin. There is also a problem with the expert panel methodology in that it is non-repeatable and may require a new evaluation for each type of LCA. The comprehensiveness of the methodologies is generally good with some methodologies enabling criteria to be included as required. The Swedish EPS and Tellus methodologies, however, do not include disamenity and the Swiss critical volume methodology excludes several key areas. The economic damages methodology is limited by the availability of economic damage figures.

Distance-to-target methodologies which use environmental standards (e.g. Dutch EPI) have clear goals which are presumably acceptable in the country of origin. Expert panels represent a small section of society so, although their goals are usually clear, they could be considered less socially representative. Panels which include representative interest

Table 1: Evaluation of Life Cycle Assessment weighting methodologies

<table>
<tr><th>Criteria
Methodologies</th><th>Transparency</th><th>Practicability</th><th>Comprehensiveness</th><th>Goal Consistency</th><th>Goal acceptability</th></tr>
<tr><td>**Swiss critical volume**</td><td>combines all assessment stages, moderately transparent</td><td>easy to use; Switzerland and German situation only</td><td>limited</td><td rowspan="2">uses environmental standards which are based on social, technical, economic and scientific factors</td><td rowspan="2">below the target level effects are assumed to be absent</td></tr>
<tr><td>**Swiss ecopoints**</td><td rowspan="2">combine classification, normalisation and valuation, moderately transparent but complex calculations</td><td>easy to use; ecopoints available only for Switzerland, Germany, Sweden</td><td>limited but main problem areas included</td></tr>
<tr><td>**Dutch EPI**</td><td>moderately easy to use, based on global data where possible</td><td>most problem areas included</td><td>weighting based on Dutch emission standards or expert judgement (small group)</td><td>Dutch target levels only acceptable in the Netherlands</td></tr>
<tr><td>**Expert/panel judgements**</td><td>combines characterisation and valuation, standard method needed</td><td>easy to use but results non-repeatable, Delphi Method time intensive</td><td>can be included as required</td><td>experts – knowledgeable but unrepresentative; panel – less knowledgeable but could be more representative</td><td>panels require consensus</td></tr>
<tr><td>**Swedish EPS**</td><td>not very transparent as calculations complex, and combines ecological, social and econimic effects</td><td>easy to use default values, but these are not simple to change</td><td>most problem areas included, but excludes disamenities</td><td>several different goals used, resource use goal unclear</td><td>willingness to pay goals depend on acceptability of using individual preferences as policy guide</td></tr>
<tr><td>**Control costs**</td><td>clear methodology, some similarities with Swiss ecopoints and Dutch EPI</td><td>weights will vary by country; toxicity scores probably the same by country</td><td>extends to all impacts via toxicity scores; disamenity excluded</td><td>control costs may be unrelated to damage</td><td>depends on degree of belief in control costs as a social consensus</td></tr>
<tr><td>**Economic damage costs**</td><td>clear methodolgy, similar in concept to control costs</td><td>easy to use</td><td>limited by availability of economic damage figures; disamenity can be included</td><td>consistent with goal of maximising economic well-being</td><td>depends on acceptability of using individual preferences as policy guide</td></tr>
</table>

groups may be considered more representative of society. The Tellus control cost methodology has a clear goal but it may not be socially acceptable as control costs may be unrelated to damages. The goals of the Swedish EPS system are inconsistent and therefore unclear. However, those goals based on 'willingness to pay' such as those used in the economic damages methodology, are consistent with maximising economic well-being. The goal acceptability of the economic damages methodology depends on the adequacy of using individual preferences as a policy guide.

Although the selection of a valuation methodology may vary with the user group's objectives, in broad terms it is possible to produce a rank order for a waste management valuation methodology. In a country which has clear, up-to-date, politically acceptable emission standards for all relevant emissions, a distance-to-target valuation system, based on these environmental standards maybe considered acceptable. However, these circumstances are likely to be rare, and also the choice of standards are likely to be arbitrary and not scientifically based. Therefore a better choice is probably environmental damage costs, provided suitable economic damage figures are available. A third choice, although less representative of society as a whole than the previous two, is a panel which includes a cross section of interested parties, perhaps in addition to a panel of experts.

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The Valuation Step Within LCA

Part I: General Principles
Stephan Volkwein, Walter Klöpffer
(Int.J.LCA 1/1, 36–39, 1996)

Part II: A Formalized Method of Prioritization by Expert Panels
Stephan Volkwein, Regine Gihr, Walter Klöpffer
(Int.J.LCA 1/4, 182–192, 1996)

International human rights conventions and international environmental laws and conventions have been used to deduce criteria for a valuation procedure for life cycle assessment. The valuation procedure relates to the impact oriented assessment of the Centrum voor Milieukunde in Leiden (CML). The panel method is suitable for comparison LCAs of two systems, or optimization LCAs. The method consists of four steps. Step one is the normalization of the results of the impact assessment. In step two, a panel of experts values the results by three qualitative criteria (time, space, hazard). In step three, a ranking diagram technique is used for a formalized priority setting and a preliminary identification of the product causing the most environmental burdens. Step four includes a sensitivity analysis and a plausibility check based on an energy and waste analysis. Discrepancies between the plausibility check and step three may cause a reevaluation of parts of the valuation, impact assessment, inventory table or goal definition of the LCA.

Ecotoxicological Impact Assessment and the Valuation Step Within LCA – Pragmatic Approaches

Rainer Walz, Monika Herrchen, Detlef Keller, Beate Stahl
(Int.J.LCA 1/4, 193–198, 1996)

Within the methodology of LCA, the impact assessment of the impact category ecotoxicity and the valuation step for all categories still pose methodological challenges. A multi-tier approach is a pragmatic solution for the impact assessment of the impact category ecotoxicity. The screening tier only makes use of information concerning substance specific characteristics in order to derive both an identification of critical substances and a comparison of products. Within the detailed tier, critical substances are analyzed in more detail, but still without site-specific information on concentrations, time or region.

Valuation combines scientific results with value judgements. Thus, it is not an objective process which can substitute decision making, but instead serves as a base for the interpretation of results. A pragmatic approach combines the results of the impact assessment with a normalization and weighting of the impact categories. Four approaches for deriving general weighting sets (population surveys, expert surveys using the delphi-technique, sustainable development, distance-to-target) are discussed and the first results obtained are presented.